Spring 2017

The Effect of Pack Size on Finish Time in the Fukuoka Marathon

Fernando E. Espinosa Jenkins

The Effect of Pack Size on Finish Time in the Fukuoka Marathon

Fernando Eduardo Espinosa Jenkins

An Honors Thesis
Submitted for partial fulfillment of the requirements
for graduation with honors in Exercise Science
from Hamline University

Acknowledgements

I write to extend my deepest gratitude to the following people who with me share a great passion for learning, caring, and working hard:

I cannot begin without thanking Dr. Lisa Ferguson-Stegall for giving me an opportunity to fly under her wing for nearly three complete years as an undergraduate student. Her passion for Exercise Science sparked my interest in the field as a sophomore student in her Exercise Physiology I course.

Special thanks goes out to the many Hamline professors who continuously challenged me in their courses. Special appreciation goes to my First-Year Seminar professor and baseball team Faculty Advisor, Rob Routhieaux, for being someone I could reach out to about anything from personal problems to academic advice during my time at Hamline. Also, thank you to only a few of my other non-academic Hamline community member supporters Jason Ellenbecker and Tracey Tennyson for continued support.

A special thanks goes out to four young men, all of whom I have lived at least two years with since my time at Hamline: Domenic Dandrea, Ryan Gick, Tanner Swenson, and Rick Tormey. I will forever share a close relationship with these men. Also, thank you to Jack Deutsch for being an incredible supporter and friend in my life.

Thank you to my brother, Lucas, who will always be my younger, taller, and smarter doppelgänger.

Lastly, thank you to my parents, Carol and Fernando, for their never-ending love and sacrifice.

ABSTRACT

Elite marathon runners have been pushing the limits of the human body, currently setting the world record near two hours. Notable factors while running include physiological, psychological, and strategic factors. Utilizing pack running may be a strategic factor to improve finish time and placement.

Purpose

To explore the effect of individuals running in various size packs on their place and finish time in the Fukuoka Marathon. This race has seen some of the most talented runners in history, as the world record has been broken twice at the Fukuoka Marathon, in 1967 and 1981.

Methods

The data set of results was received through a collaboration with Dr. Michael Joyner, of the Mayo Clinic. Subjects running in the Fukuoka Marathon in Fukuoka, Japan were all male (n=240). Marathon race times and splits was analyzed from the year 1967 through 2014. Race splits were recorded every five kilometers and at the halfway point. Only runners who finished in the top five were used to record pack sizes. Pack sizes were counted for every top five finisher at each split and a mean pack size was calculated. Finish times were normalized to the winning time of each race. One-way ANOVA test was performed to quantify the effect of mean pack size on finish time.

Results

No significant correlation was found between mean pack size and finish time for top five finishers (p=0.793). Regressions of mean pack size during the first half, second half, and entirety of the race yielded a slope of zero.

Conclusion

Although pack size and finish time were not significantly correlated, there were non-significant trends within the data that showed possible relation between place, size, and the duration of a pack that an individual ran with. Further studies should explore psychological benefits of racing in a pack, pack sizes outside of the top ten finishers, whether place within an individual pack is relevant to finish time, how individuals changing packs effects race dynamics, and if top finishers should be excluded from the pack pacing hypothesis.

Introduction

Many factors determine how quickly a person is able to run a marathon, including physical, psychological, and environmental conditions. Running as a group, commonly known as a pack, is a racing strategy that is commonly seen when running long races such as a marathon. It is not well known how this is strategy directly effects physiological and psychological systems to make a runner acutely run a faster time than if they where running apart from a pack. Recreational runners may anecdotally notice a benefit in running with a few racemates, while elite runners tend to use this pack theory to their advantage when racing for personal records (Gaudette, 2012).

Physiological factors play an important role in taking seconds to minutes off of a fast marathon time. Advancements in physical training have produced some of our best athletes in the present day. Progression in understanding how to improve human performance, technological advances used in training, and the globalization of training equipment have perfected running as a sport. These advances help to force humans, seemingly, to their physiological limits of performance. We have seen advances shown through the steady decrease in marathon record times since finish times have been recorded. The question must be asked, will we ever break the 2:00:00 finish time? The running world has developed a fascination with the possibility of reaching this time milestone. While experts say we will absolutely crack this barrier, they also ponder whether we are nearing the ultimate benchmark marathon time. Runners seem to be approaching the brink of human performance capabilities. Dr. Joyner produced a research study in 1991, *Modeling: Optimal Marathon Performance on the Basis of Physiological Factors*, targeting the limiting factors in human performance. The three variables measured that have yet to have been seen in optimal combination are: maximal oxygen uptake (VO2 max), lactate threshold, and running economy. Runners who are able to intake more total oxygen are better off because they are able to deliver more oxygen to their muscles. Lactate threshold is the point at which during exercise lactate levels in the blood begin to exponentially increase. Delaying this point through training can cause runners to perform better due to a less acidic environment in the blood that makes runners want to stop due to fatigue. Running economy is how efficiently a runner uses oxygen at a given velocity. Joyner suggests that given realistic values of the three variables from current runners, a single runner with elite values of VO2 max, lactate threshold, and running economy is physiologically capable of running a sub-two-hour marathon.

Finish times have been decreasing since the start of recording finish times in 1908. Times have appeared to be decreasing somewhat exponentially since then and even at a greater rate since 1998 (Joyner 2011; Hutchinson 2014).

The current marathon record time for men was set in 2014 at 2:02:57 by Dennis Kimetto of Kenya during the 2014 Berlin Marathon. The world record 40 years prior in 1974 was set at 2:09:12 by Ian Thompson of the United Kingdom, a difference of six minutes and fifteen seconds. Look back another 40 years, when in 1934 the world record was 2:30:01 set by Harry Payne of the United Kingdom, a difference of over 20 minutes. This suggests that it is now more challenging to take minutes, let alone seconds, off of the marathon world record than ever before. Factors like globalization of running as a sport have opened the door to allow a larger pool of athletes to compete. Also, running as a profession or for monetary reward has expedited record finish times. Nonetheless, human performance physiologists have evaluated every aspect of training and preparation to try to enhance performance. Of these elite athletes, some experts wonder at what point do we see the pinnacle of human potential in this sport?

In 1991, Dr. Michael Joyner, of the Mayo Clinic predicted a minimum possible human marathon time of 1:57:58 (Joyner, 1991). A model later developed by Joyner, within realistic values, idealized many applicable factors to determine this mark. This hypothetical runner would have exceptional VO2max and running economy values, two factors that have yet to been seen in combination at the highest level. For example, East African runners tend to have lower VO2max, but are often very mechanically efficient when running (Joyner 2011). Also, this runner will likely be 170 centimeters tall and 56 kilograms in weight (Joyner 2011). Other characteristics likely to be seen in this hypothetical runner based on marathon trends according to Joyner (2011) include: early exposure to high altitude, significant physical activity levels throughout the lifespan, and a runner of either Kenyan or Ethiopian descent. These latter factors are obviously uncontrollable for a runner, therefore there must be other variables to consider while running a race.

What role does the presence of other runners play to an individual when running a marathon? The answer to that question may be where runners can make up ground. Running in packs has shown widespread anecdotal benefit. Runners may feel more confident, have runners they can visually see to keep them motivated, and overall report quicker times (Hamilton, 2014). However, the benefit of running in a pack has not been shown statistically.

Purpose

To determine the effect of individuals running in various sized packs on their place and finish time using 48 years of data from the Fukuoka Marathon, in Fukuoka, Japan.

Hypotheses

1. Runners with comparatively greater average pack sizes during the first half of the race will place higher in the race.

2. Runners with comparatively greater average pack sizes during the second half of the race will place higher in the race.

3. Runners with comparatively greater average pack sizes during the entirety of the race will place higher in the race.

4. Second half pack sizes, on average, will be smaller than first half pack sizes.

Significance

If statistical significance is shown that running in packs is advantageous to performance while running a marathon, this can provide elite runners with a definitive strategy to use not only to chase their own personal records, but also to continue to push the current marathon world record.

Review of Literature

It is thought that marathon runners racing alongside an opponent are more likely to finish faster than if running a race solo. However, this anecdote has yet to be confirmed scientifically and statistically. Only very recent research has began to explore the idea that running in packs is beneficial by noting the cumulative effects of metacognition, drafting, and intra-pack dynamics. One recent study has shown that if a runner is in the pack that is most comparable to their abilities that they will see improved results over if they had run solo (Hanley, 2014). In this review I will discusses literature that is relevant to the preceding concept.

Intra-pack Dynamics

New studies related to various endurance competitions are being produced. Within these studies there is more attention being put on understanding why racing in groups is preferable. Brian Hanley (2014) published a study from IAAF Half Marathon Championships between 2007 and 2014. The study focused on determining the effectiveness of different racing strategies, he found that most successful runners were all able to maintain pace for the majority of the race and then speed up towards the finish. Those who varied their speed often or slowed towards the finish were not as successful (Hanley, 2014).

The most effective strategy in Hanley's study was shown to be for runners to run in the same packs for the whole race, assuming that they have similar abilities (Hanley, 2014). This strategy is consistent with Hanley's findings in his succeeding study, *Pacing, packing and sex-based differences in Olympic and IAAF World Championship marathons* (2016). Marathon runners should have an idea of which racers have similar motivation and abilities (Hanley, 2016). Runners can benefit by running alongside these competitors because they provide the best source of motivation for the duration of the marathon. A 2010 study by Viru et al. called, *Competition Effects on Physiological Responses to Exercise: Performance, Cardiorespiratory and Hormonal Factors*, focused on the mechanisms explaining why runners show increased performance in competitive conditions. Runners simulating a competitive environment running to exhaustion on a treadmill showed a 4.2% increase in performance and a 4.4% increase in peak VO2 max response, as compared to non-competitive conditions (Viru et al., 2010). In competitive situations runners show increased motivation, increased oxygen uptake, and an increase in cortisol response that all may boost endurance performance (Viru et al., 2010). This explains why running alongside an opponent in a pack may in-turn push runners to further individual physiological limits.

A second good, yet imperfect strategy was to run in "nomadic packs," as shown by Hanley's IAAF Half Marathon study (2014). These runners, like those who ran in consistent packs, ran alongside their competition for the vast majority of the race. However, runners with the nomadic pack strategy changed which packs they ran in. For example, if a runner is confidently leading a pack they may choose to speed up their pace to join another rather than running solo in "no-man's-land." This may also put the pack that was left behind at a disadvantage, running with one less racer. If this pack was small to begin with, the one runner speeding up may be the make a significant difference to the pack losing motivation and not performing to the best of their abilities (Hanley, 2014). The nomadic pack racing strategy will be further be explained in the Future Directions section of the Discussion.

The least effective strategy, according to Hanley, was to try to remain in packs that are too fast for a runner (2014). Runners who dropped off the fastest, slowing pace dramatically, were those who ran in packs that were too fast for their abilities. Alternatively, an entire pack may be over-performing and all runners may slow rapidly later on in a race. According to Hanley, the best way to avoid this as an individual is to ensure runners check their split times periodically and have an understanding of what they should be going into a marathon (2014).

The research done in Hanley's *Pacing Profiles and Pack Running at the IAAF World Half Marathon Championships* study was groundbreaking in providing a statistical basis behind why runners should be particular with who they choose to run alongside (2014).

Metacognition

The idea of one's conscious awareness of internal thought is quite complex. Known as metacognition, being able to control or understand individual thought processes is likely a legitimate way gain a performance advantage, particularly in athletics . Being able to have proactive thought about the environment ahead is advantageous. Also being able to have plastic, reactive thoughts is advantageous (Brick et al., 2016).

Brick et al. (2016) researched how being able to cognitively self-regulate one's internal experience may help to see better results during endurance performance. This research is especially applicable to running a marathon where runners must constantly manage their pace and make adjustments based off of physiological responses. There are two parts to metacognition mentioned by Brick et al. (2016): metacognitive skills, which include planning and monitoring, and metacognitive experiences, which include feelings and judgements. Metacognitive skills are focused on minimizing distractions and ensuring that a runner will be prepared to perform at their highest level during the given race. Metacognitive experiences is focused on adaptation and being able to temporarily adjust focus to create the most effective strategy in a given moment. A combination of controlling skills and experiences helps us to understand how important the psychological aspect is to performing in an endurance event like running a marathon.

In another study, Brick et al. (2014) showed that when an endurance athlete dedicates attention to an endurance task, the athlete will likely perform better. They will be better suited to maintain their running pace, effort, and physical responses to discomfort. Metacognition plays an important role to pack running because during a race runners must consciously be aware of other runners around them. Constant and continuous self-regulation is vital to a runner maintaining positioning in pack. Runners have to think proactively yet be adaptable to any quickly changing pack dynamics or rapid internal fatigue during the race. Remaining in control of one's thoughts can help focus and attention during an endurance competition.

Drafting

During prolonged exercise like running a marathon, it is imperative to micromanage energy consumption from start to finish. Minimizing energy output allows runners to make the most of aerobic energy production, sparing the use of muscle glycogen. One of the ways that has been proven to decrease energy output is to run behind an opponent in a technique called drafting (Davies, 1980). Drafting is useful because it minimizes air resistance that is created when a runner is in motion (Davies, 1980). For this reason, positioning within a pack plays an important role with regards to being energy efficient while running (Davies, 1980).

A 1980 study by C.T. Davies, *Effects of Wind Assistance and Resistance on the Forward Motion of a Runner*, first provided evidence that indeed there is a correlation between racing position and energy consumption. Davies found that the energy cost of overcoming air resistance on a calm day outdoors was 7.8% for sprinting (10 m/s), 4% middle-distance (6 m/s), and 2%

marathon (5 m/s) running (1980). Applying this to marathon racing, most runners will be at or around 5m/s (5:22 per mile pace), meaning that a runner drafting a leading opponent on a calm day will use approximately 2% less energy upon completion of the race (Davies, 1980). While this may seem negligible, it is not. Putting it into perspective, for the same pace, drafting one meter behind a competitor on a still day equates to about 1 second of time to make up for every 400 meters (Davies, 1980). These numbers are only considering calm days; thus, on days when there is a significant headwind, even more energy is required for the same pace.

Davies (1980) also considered exact position behind a front runner by experimentally controlling air resistance against runners on a treadmill. His findings show that there are ideal distances behind and laterally when drafting. Running over a half meter to the side of and behind a frontrunner showed a marginal decrease in air pressure felt compared to the value taken of the frontrunner of 91% (Davies, 1980). Runners near one-half meter directly behind a frontrunner felt a decrease in air resistance of 0-2% of frontrunner resistance (Davies, 1980). This value means that essentially no wind resistance was felt between distances of 0.4 and 0.8 meters directly behind a frontrunner. Combining the findings of energy conservation and wind resistance felt, we can say that the ideal position to be in for the majority of a race is around a half meter directly behind a frontrunner. Practically speaking, it is possible to run on the heels of a frontrunner. However, if this is unattainable due to the possibility of coming into contact with another runner, wind resistances felt at a meter directly behind a leader are still near 10% of actual air resistance, according to Davies (1980). Therefore, the significance of drafting during a marathon race further supports running behind someone or in a pack for the majority of a race. Runners not leading, but rather in the heart of a pack are more likely to conserve energy due to excluding air resistance, thus are more likely to make a surge towards the finish line to place higher. This concept supports running in a pack during a marathon race.

Methods

The marathon times of top ten finishers were collected from the year 1967 through 2014 during the Fukuoka Marathon in Fukuoka, Japan. The 42.195 kilometer race course has been unaltered for the entirety of the 48 year span and is ran annually in December. Race split times for each runner were recorded at every five kilometer checkpoint as well has at the halfway mark (21.1 kilometers). All racing subjects were male of various nationalities. Other relevant demographics were not provided with the dataset.

As stated above, only data of the top ten finishers was available. To account for any overlap or miscalculation in pack sizes, only the top five finishers were used to analyze pack size and finishing place in the race. This is because the data provided did not show when the eleventh, twelfth, etc. finishers were maneuvering in and out of packs, if at all. For instance, if a runner was in the top ten for the vasty majority of the race, but fell back and finished eleventh or worse, we would have seen a underestimation in pack size. By taking the top five finishers while accounting for the next five behind, there is a higher certainty that the eleventh and beyond finishers were not providing misleading pack size data.

The dataset was received from Dr. Michael Joyner of Mayo Clinic - Human Integrative Physiology Laboratory. Data was initially very raw, consisting of hundreds of split times in a 117 page Microsoft Word document. A way to consider every time and compare it to others within a race was developed. For intensive purposes of this study, a pack was defined as being any one runner plus any other competitor within a maximum of six seconds. This value was determined based on widespread race tendencies. While this may seem like a large gap between runners, there were few cases for the hundreds of times in which a runner was running solo, with a runner two to six seconds behind them. This six second spread was most importantly necessary to account for larger packs. Quite frequently large packs stretched across a six second span, each individual within one second behind the next. This is enough separation for runners to benefit from the effects of drafting. In nearly every pack, there was a lead runner and all runners behind fell within six seconds of the pack leader. For this reason, a six second pack spread was most appropriate given the data.

Average pack sizes were compared graphically to each top five finisher in each race. Statistical analysis was performed using one-way analysis of variance using SPSS statistical software. Linear regression analysis was performed to detect variation in mean pack sizes by finish place.

Results

Statistical analysis of pack size against finish place for the top five runners in each race showed no difference between placing in terms of mean pack size for the race as a whole, first half, and second half. Statistics for the entire race showed little to no variation in place and average pack size ($p = 0.793$, $p > 0.05$). All of the mean pack sizes for each first through fifth place finisher show pack sizes near six to nine runners. Statistics for first half and second half mean pack sizes showed much of the same. Runners, even with varying finish places, ran in the same size packs throughout the race. First half packs did show larger pack sizes as would be expected with an average just under ten runners per pack. During the first half of the race, runners who finished in the top five were more likely to run together in a larger pack. As the races progressed, runners began to separate, as shown through the data in the second half of the race. Second half average pack sizes were smaller, averaging from three to five runners per pack. Linear regressions showed no slope for all three data sets. Graphs of the three analyses are on the following pages.

Graphs

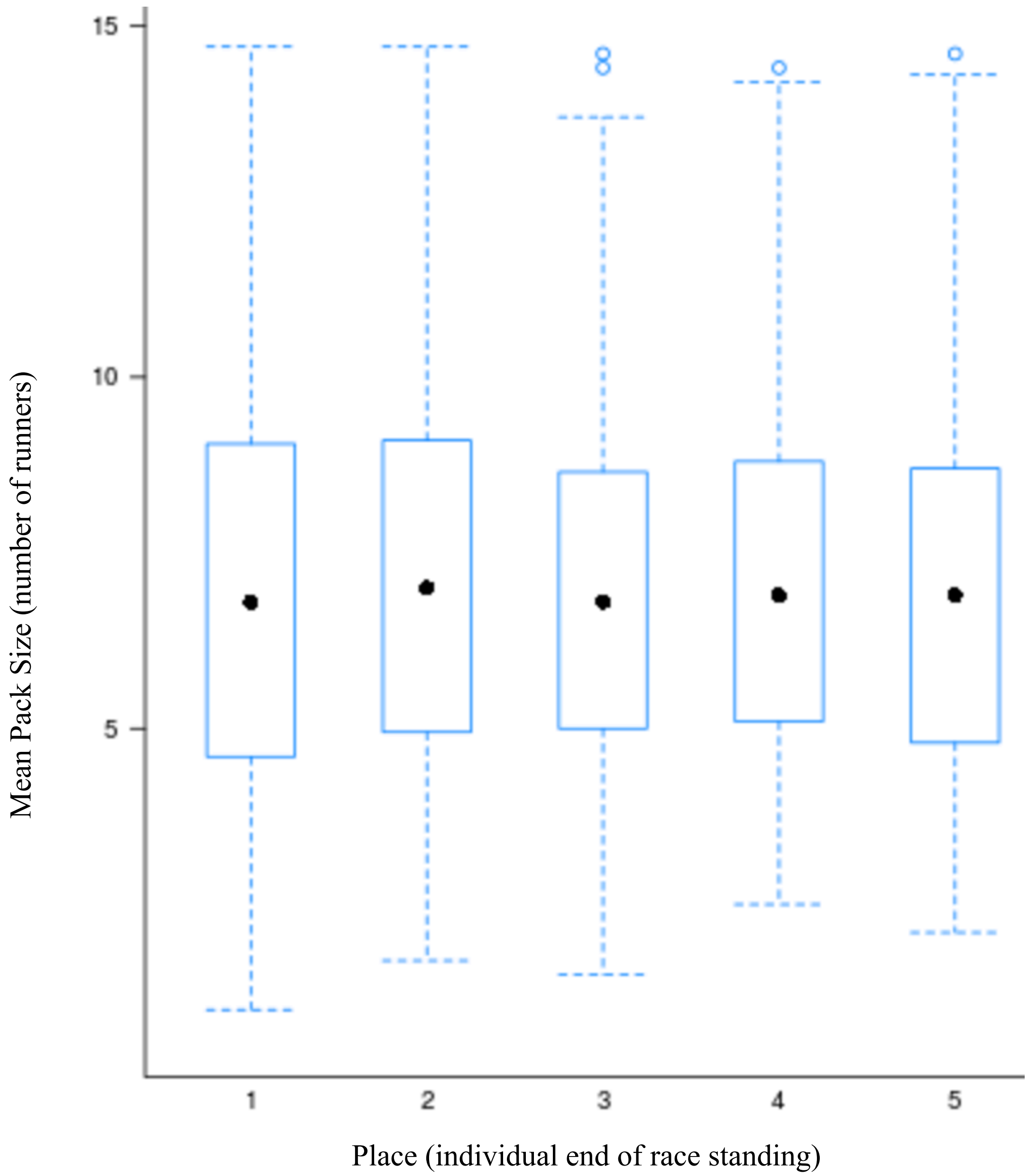

Figure 1. Mean pack size and finishing place

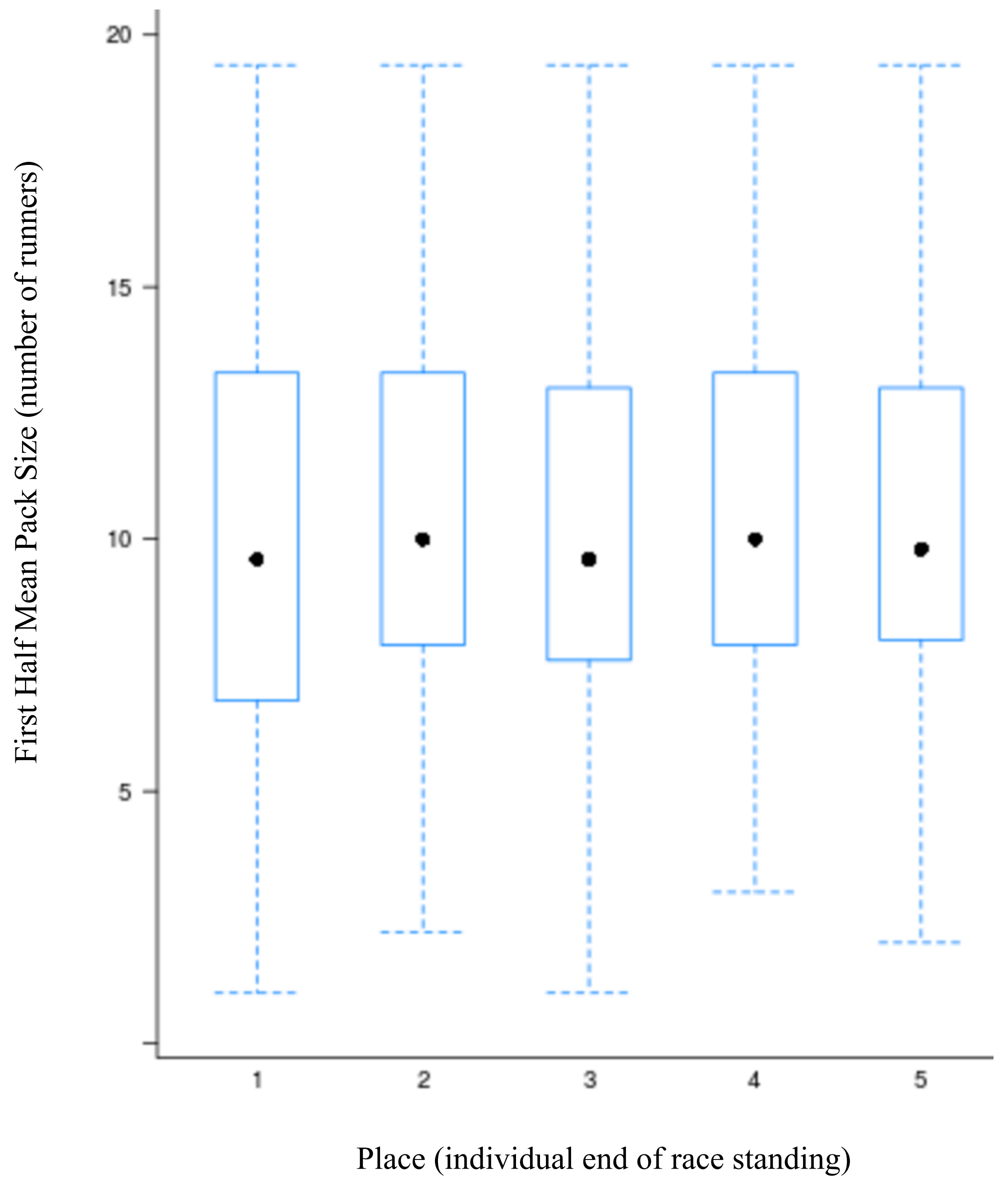

Figure 2. First half mean pack size and finishing place

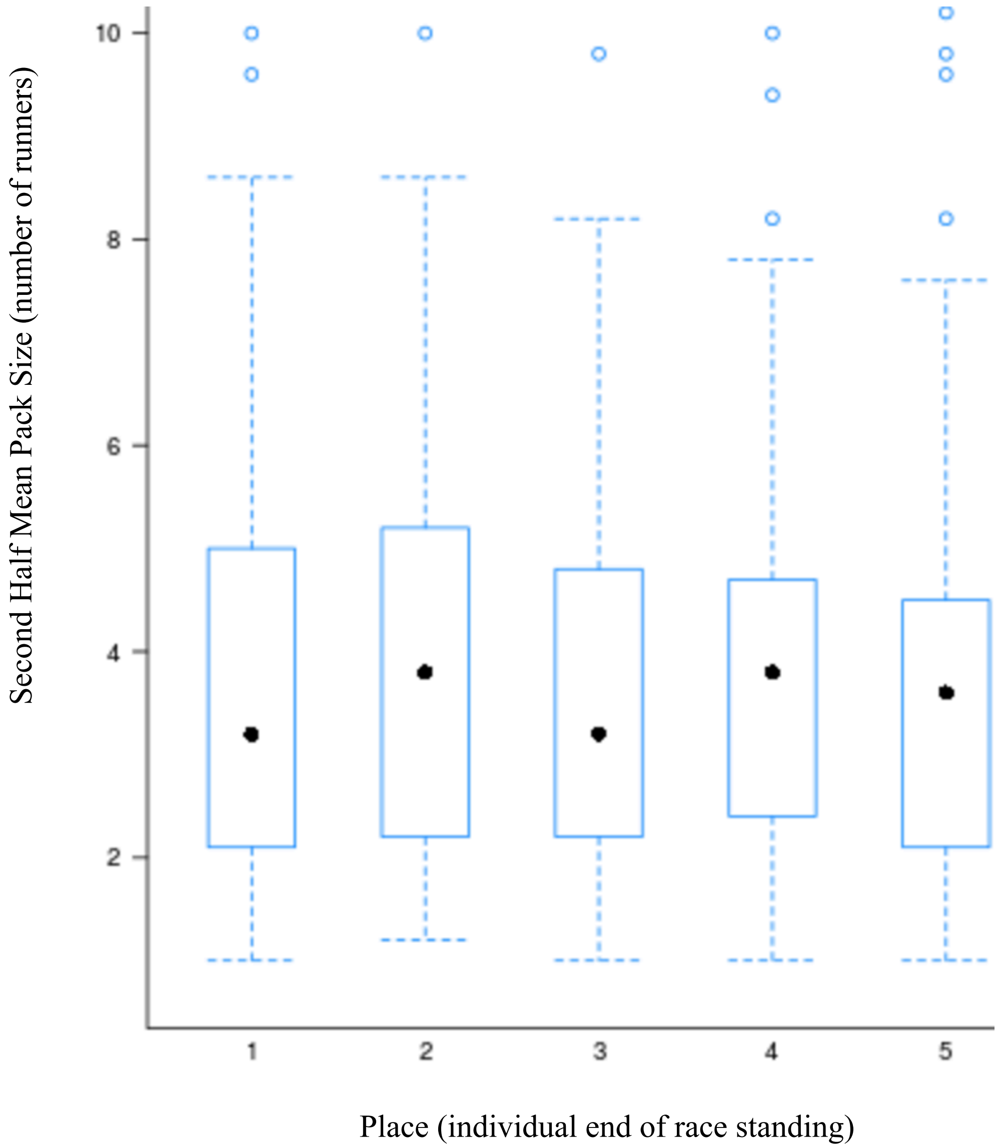

Figure 3. Second half mean pack size and finishing place

Discussion

Results showed no significance between average pack size throughout the race and finish place. For this race running alongside more competitors did not correlate with a higher finish place. This investigation introduces the multiple that need to be considered when performing this type of experiment with human subjects including but not limited to psychological, physiological, and social factors.

Future studies should consider the effects of nomadic pack jumping. This is to say that runners may not stay with a given pack for the entirety of a race. Some more recent studies consider psyche within a single pack (Brick et al., 2016). For example, if a runner is struggling to keep up with a fast pack, it may be beneficial to drop back to the next closest group of racers. The opposite may be true in that if a racer is carrying a slower pack, it may be beneficial to speed up to catch the nearest pack. At this point the runner may gain a psychological drive by seeing faster racers ahead of them as opposed to not having the motivation of in sight. This changing of positions within the race should be researched more to better understand how even a tiny adjustment like this in racing strategy may still help racers shave off seconds from their finish times.

The extent to which running within a pack gives runners a psychological advantage is still unknown. With larger data sets, we would be able to explore the effects at different abilities of runners. Pack strategy may be most effective for runners who are not elite, nor likely to finish last. The middle ground runners have the most to gain if they are chasing elite packs.

Another area that needs to be further considered is how the top elite runners, the ones challenging current marathon records, are able to run during the second half of marathon sans packs. One may question how strong of an impact running in packs truly has if these top runners have the ability to lead a pack for the majority of a marathon. Elite runners may be better running alone depending on the abilities of the field of each race. The psychology of running in a pack may benefit each runner differently.

Future Directions

Due to the unpredictable nature of running a marathon, it would be beneficial to have prior information on runners and their tendencies going into a race. Also, demographics of each runner would be interesting to consider. A new research methodology may include recording times of two runners who train for half or whole marathons. From there, participants could be monitored by researchers recording tendencies of running as a part of a pack. With the assumption that two racers have essentially the same marathon times while running alone and report feeling physiologically as well as when they were training, the effect of pack racing in mere identical runners could be more easily observed.

One way that more data can be collected in an easy and effective manner is to perform qualitative interviews after a marathon race. It may be beneficial to ask questions directly after a race of how beneficial a runner thought running in a pack was. By providing a simple scale of perceived benefit, we can compare that value to how often a runner was in a pack, their average pack size, and where they finished the race. This would also give us a good overall sense of how frequently runners utilize running in packs. Oppositely we could consider runners who tend to stay their own pace and mentally block out where other runners are positioned.

Limitations

Although 48 years of data was provided, each race year only contained, at fewest, the top ten finishers. Ideally one year of data set would have included every single racer who started the race. This would have provided a more clear understanding of which runners benefited from running in a pack as well as the chance to compare runners who finished farther apart from each other than just the top five.

In addition, being only able to analyze pack sizes for the top five finishing runners in each race likely does not tell the entire story. Runners who finished this high may already be at a much higher level of ability above the succeeding finishers, meaning that they are more likely to run alone for at least part of the race. This is to say that there may be less variation in ability among middle finishers, in which running in a pack might show a greater influence.

Split times were recorded at each five kilometer checkpoint as well as the halfway point. A runner within a pack at a checkpoint could have been running alone or even with another pack between the split times recorded.

Racing in teams was also not considered. Based on the countries of origin provided along with the data, we can assume that teams did not play a large factor, especially in the top finishers who were from various countries. However, it is entirely possible that runners from different countries agreed to pace each other during the race. This may especially be true if they have raced against each other previously and were aware of an opponent's capabilities.

Lastly, but very importantly, for each race no weather data was provided. We know that the direction of wind has a factor in the amount of energy necessary to perform relative to if it was a calm day. That is to say that if conditions were windy, primary blowing against the trail, runners may have opted to stay in packs to nullify the negative effect of running upwind. We do not know how environmental conditions differed between years such as temperature, wind, precipitation, etc. that all could effect the outcome of a race.

Conclusions

Statistical analysis showed that there is no discernible effect of pack size on finishing place for the Fukuoka Marathon top five finishers from 1967 through 2014. Some limitations previously stated may have limited the potential for detecting the true benefits in this study. Future research should include statistical data from all finishers of the race. This would likely give a more accurate depiction of pack sizes and would have less clustering near the top finishers. Additionally, multiple elite races across the world should be analyzed to determine if results are consistent on different courses.

Non-significant trends in the data showed instances when racers began running in a pack with the first or second place runners and then fell behind, running solo while the top runners continued to run together. These types of trends are ones that would show clear benefit in pack racing if runners lose time between splits. The varying nature of a marathon race can prove to be unpredictable; however, competitive runners should continue to benefit from the psychological and physiological benefits of running in packs.

Works Cited

Brick, N. E., Macintyre, T. E., & Campbell, M. J.. Thinking and Action: A Cognitive Perspective on Self-Regulation during Endurance Performance. Frontiers in Physiology Front. Physiol., 7. 2016.

Burfoot, Araby. Marathon Smarts. Runner's World 40.11: 87-91. Consumer Health Complete. EBSCOHost. 2005.

Davies, C. Effects of wind assistance and resistance on the forward motion of a runner. Journal of Applied Physiology, 48(4), 702-709. 1980.

Gaudette, J. Runner’s World. Learn to Pace Like a Pro. 2012.

Hamilton, M. Runner’s World. Running Friends Are Friends with Benefits. 2014.

Hanley, B. Pacing profiles and pack running at the IAAF World Half Marathon Championships. Journal of Sports Sciences, 33(11), 1189-1195. 2014.

Hanley, B. Pacing, packing and sex-based differences in Olympic and IAAF World Championship marathons. Journal of Sports Sciences, 34(17), 1675-1681. 2016.

Hutchinson, A. Runner’s World. What Will It Take to Run a Two-Hour Marathon? 2014.

Joyner, Michael. Modeling: Optimal Marathon Performance on the Basis of Physiological Factors. Journal of Applied Physiology 70.2. 1991.

Joyner, M. J., & Coyle, E. F. Endurance exercise performance: The physiology of champions. The Journal of Physiology, 586(1), 35-44. 2008.

Joyner, Michael J. New Marathon Record An Analysis & Next Steps. Human Limits RSS. N.p., 2014.

Joyner, M. J., J. R. Ruiz, and A. Lucia. The Two-hour Marathon: Who and When? Journal of Applied Physiology 110.1: 275-77. 2011.

Marathon world record progression. (n.d.). Retrieved January 30, 2017, from https://en.wikipedia.org/wiki/Marathon_world_record_progression

O’Neal, Eric K. et al. Half-Marathon and Full-Marathon Runners’ Hydration Practices and Perceptions. Journal of Athletic Training 46.6: 581–591. 2011.

Viru, M., Hackney, A., Karelson, K., Janson, T., Kuus, M., & Viru, A. Competition effects on physiological responses to exercise: performance, cardiorespiratory and hormonal factors. Acta Physiologica Hungarica. 97(1). 2010.